

Presentation at the First Plenary Meeting
of the Advisory Committee on Acoustic
Impacts on Marine Mammals
3-5 February 2004
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Marine Mammal Commission or the Advisory
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Mammals.*

Overview of Sound Sources in the Marine Environment

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**Marine Mammal Commission
February 3, 2004**

INTRODUCTION to ACOUSTICS: Simple Harmonic Oscillator

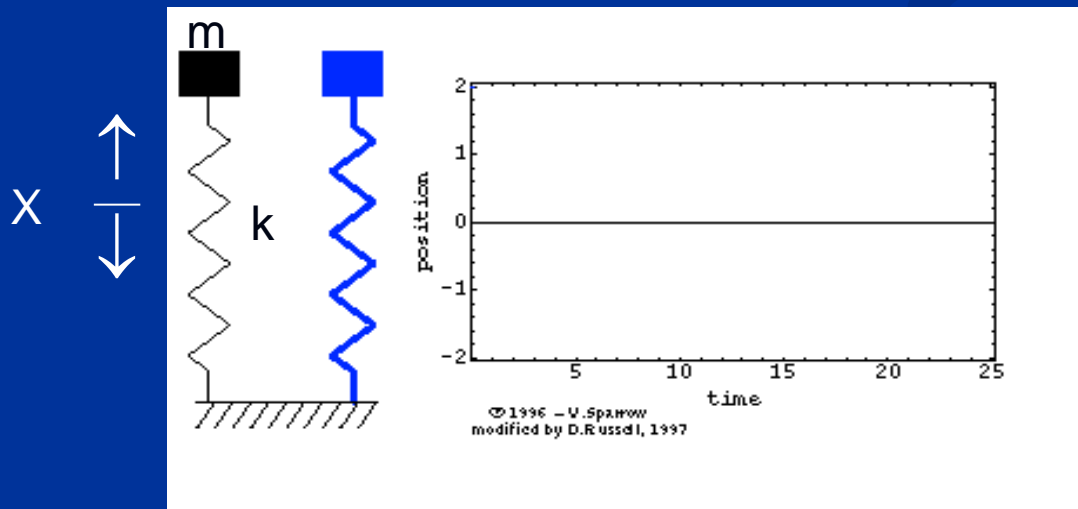
Parameters:

m = mass; k = spring constant; R = damping

Resonant Frequency: $\omega_o = \sqrt{k/m} = 2\pi\nu$

Two Kinds of Energy:

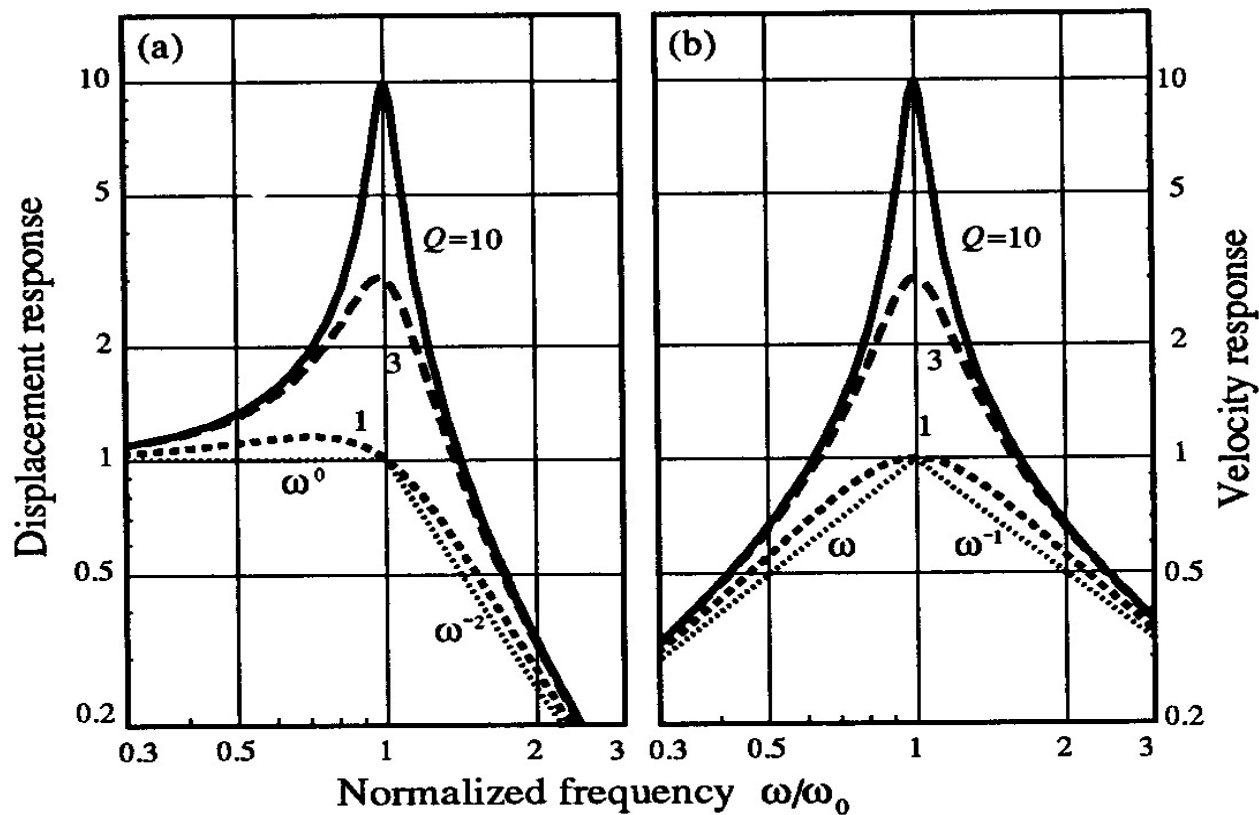
Kinetic $T = \frac{1}{2}m\dot{X}^2$ Potential $V = \frac{1}{2}kX^2$ Total = $T + V$



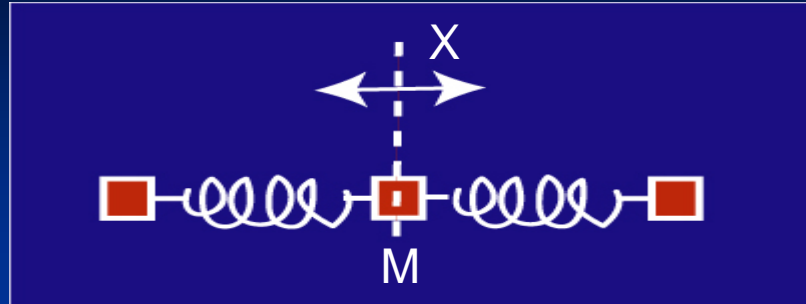
Simple Harmonic Oscillator

Quality Factor: $Q = \frac{\omega_o m}{R}$

Ratio of the mechanical energy at resonance to the energy dissipated per cycle.



Acoustic Waves in Infinite Media



Two Kinds of Energy:

Potential \sim Pressure² and Kinetic \sim Velocity²

Pressure is a scalar, Velocity is a vector (has direction)

Acoustic Intensity (A_i) – Energy flow per unit area per unit time

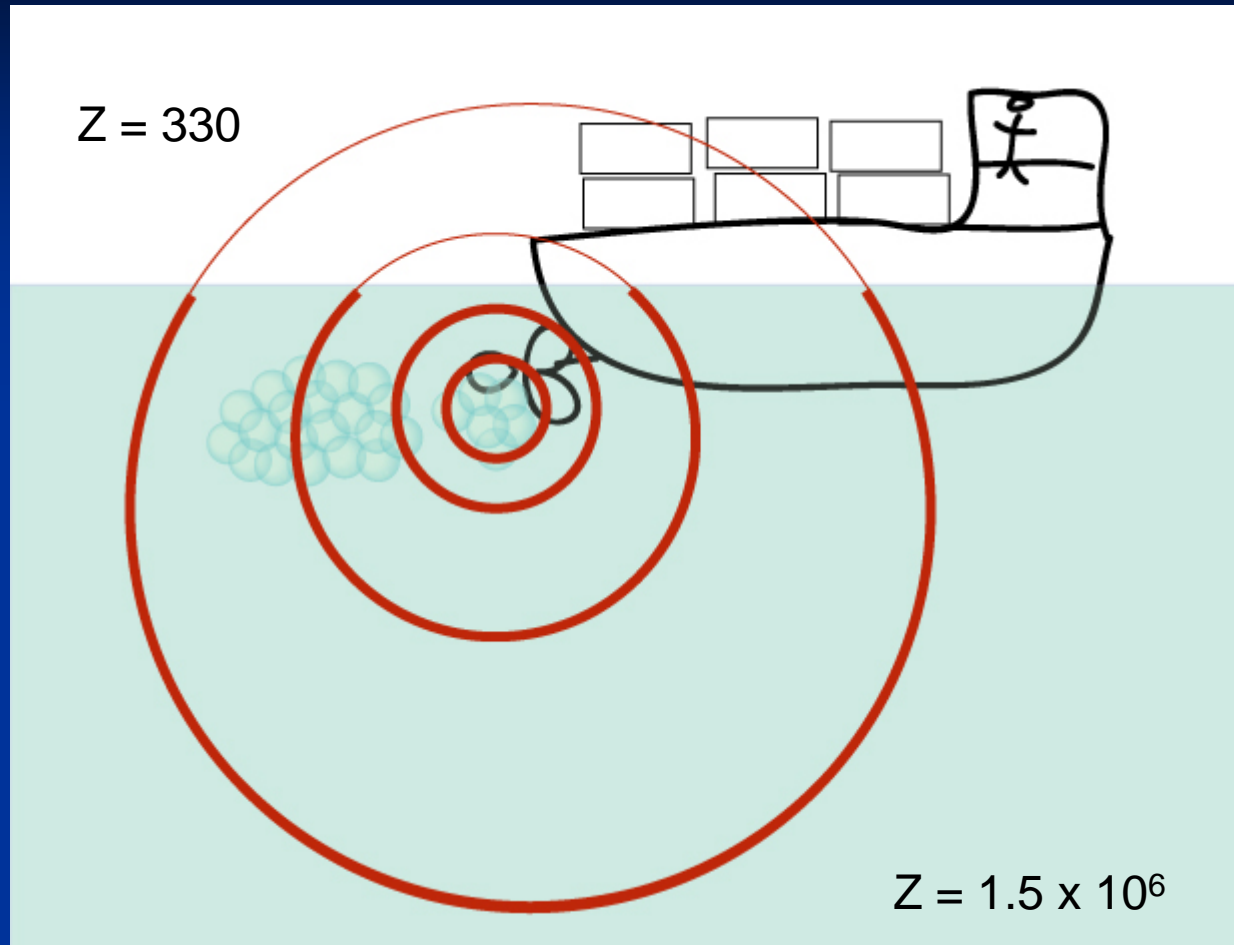
$$\vec{A}_i = p\vec{v}$$

How to estimate Acoustic Intensity when only measure Pressure?

Use Acoustic Impedance ($Z = p/|\vec{v}|$) – but only correct for planewaves

The (typically incorrect) planewave assumption lies at the heart of Underwater Acousticians use of $A_i = p^2 / Z$

Why Ocean Noise does not Deafen Sailors?



Loss in acoustic intensity crossing the air-sea boundary
For a given particle velocity $p_{OCEAN} \gg p_{AIR}$

Comparing Acoustic Sources

Fourier Transform –

Analyze a Time Series into Frequency Components:

Power Spectral Density – $\mu\text{Pa}^2 / \text{Hz}$

Standard for NOISE to use 1 Hz wide frequency bins

Alternatively use OCTAVE or 1/3 OCTAVE bins

$$\Delta \text{ dB} = 10 \log_{10} (\text{Bandwidth})$$

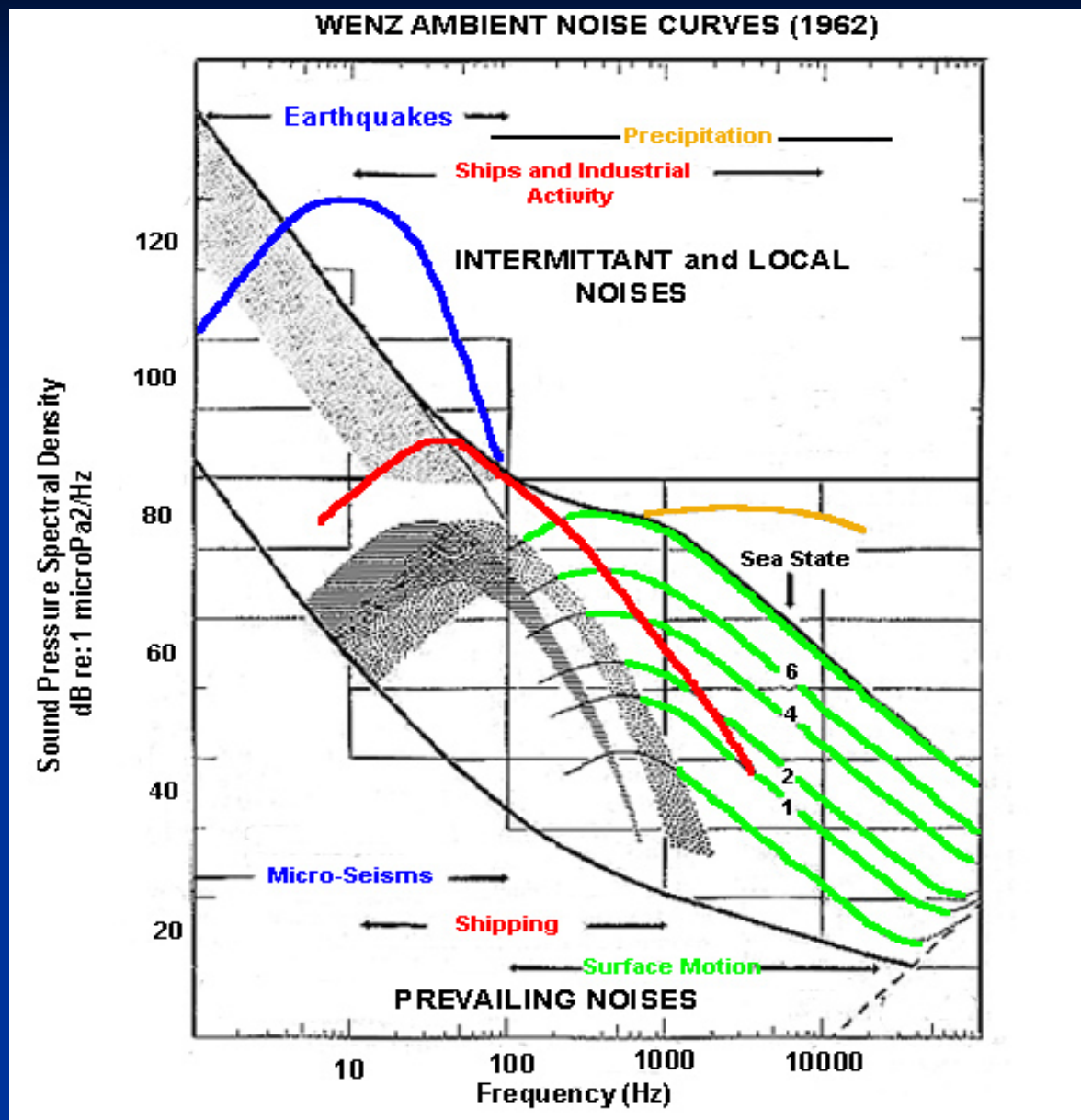
Ping “Energy” – Accounts for Signal Duration

$$\Delta \text{ dB} = 10 \log_{10} (\text{Duration})$$

Array “Energy” – Accounts for Multiple Sources

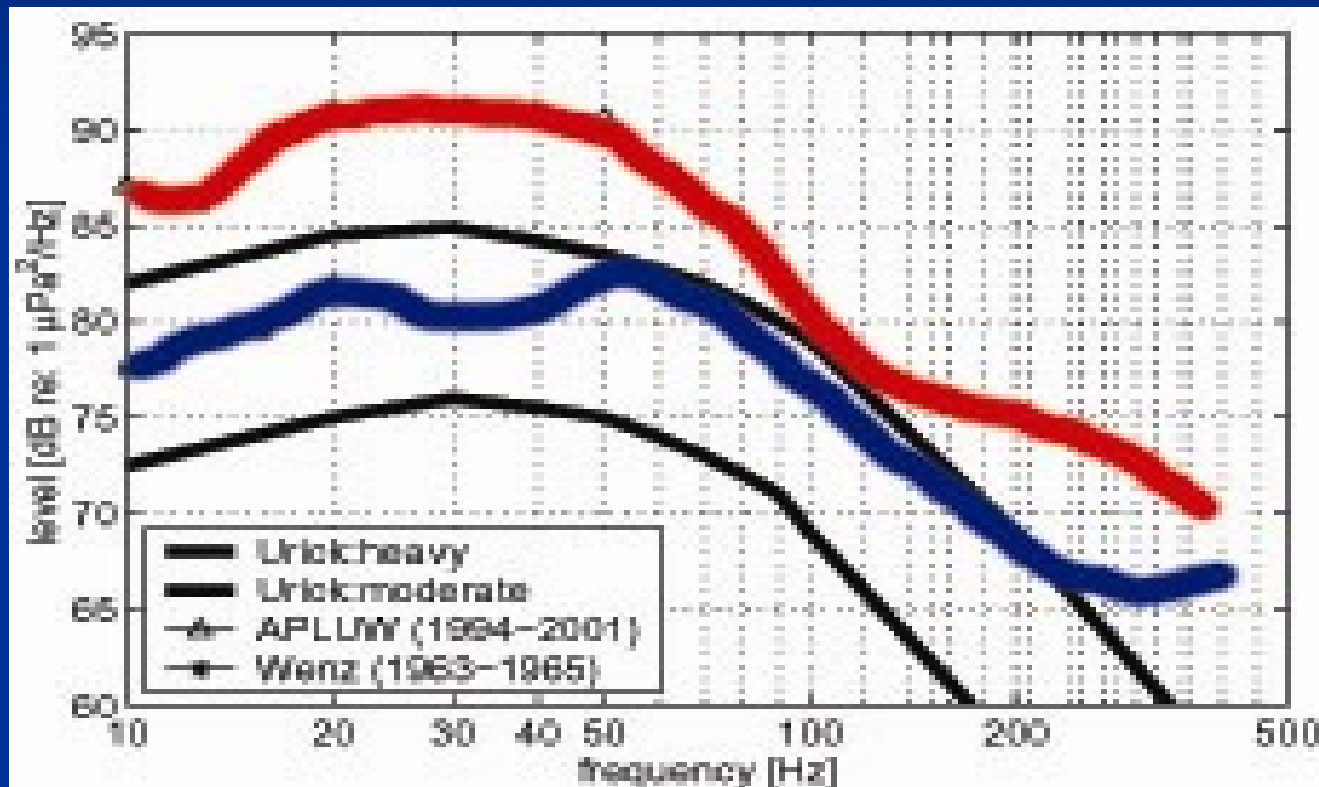
$$\Delta \text{ dB} = 10 \log_{10} (\text{Number})$$

AMBIENT NOISE IN THE OCEAN



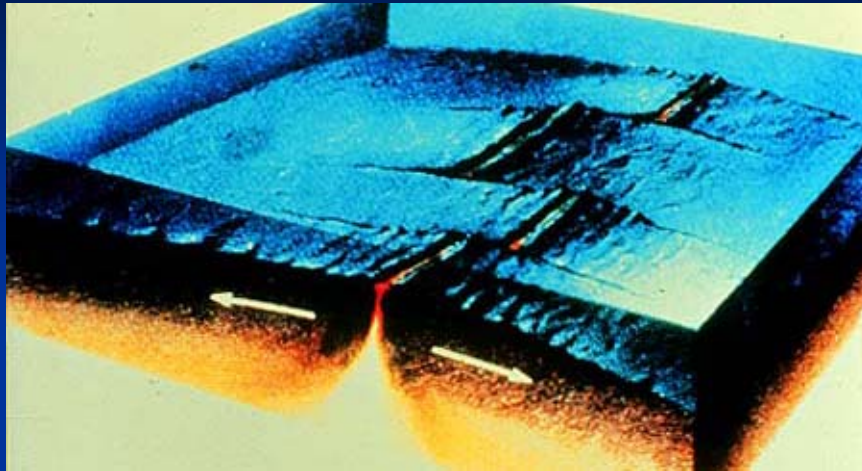
Ambient Noise – Long Term Trends

Point Sur SOSUS Array – 1964 (Blue), 2001 (Red)

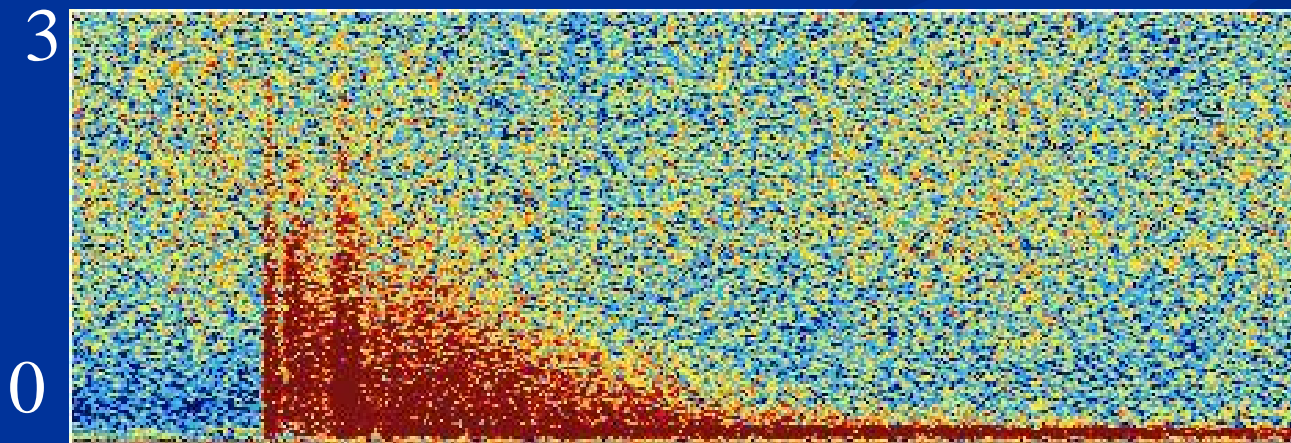


Shipping noise in N. Hemisphere has increased ~3 dB/decade

Ambient Noise - Earthquake



Frequency (KHz)

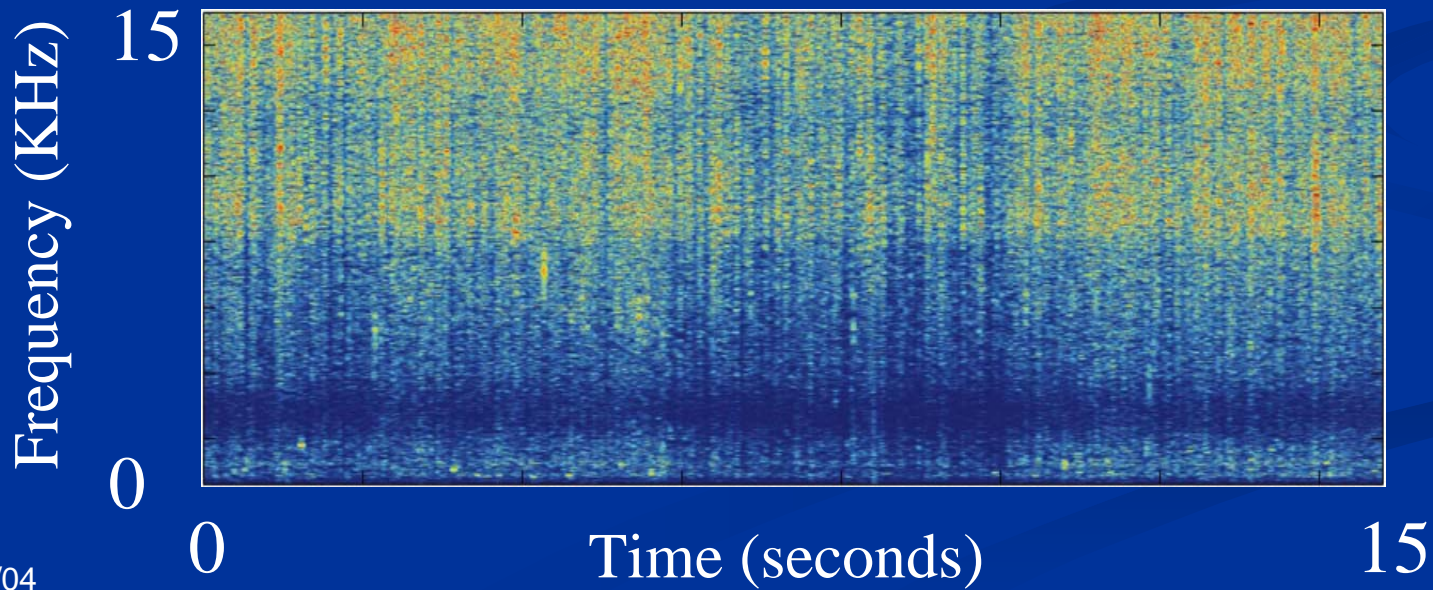
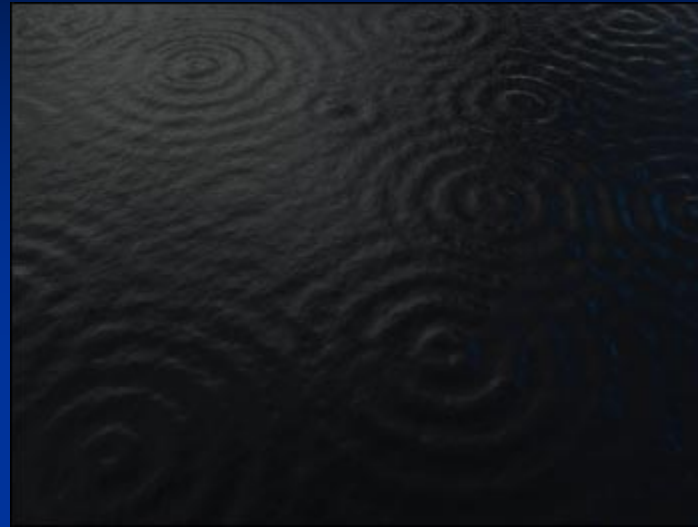


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Time (seconds)

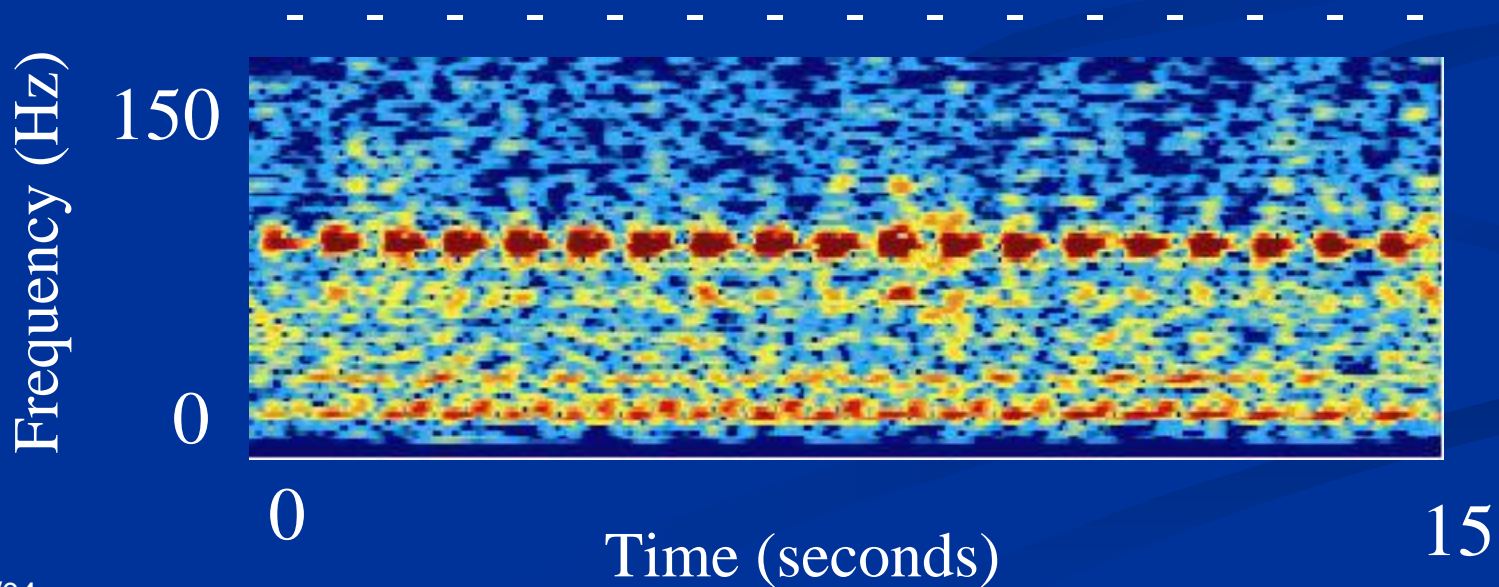
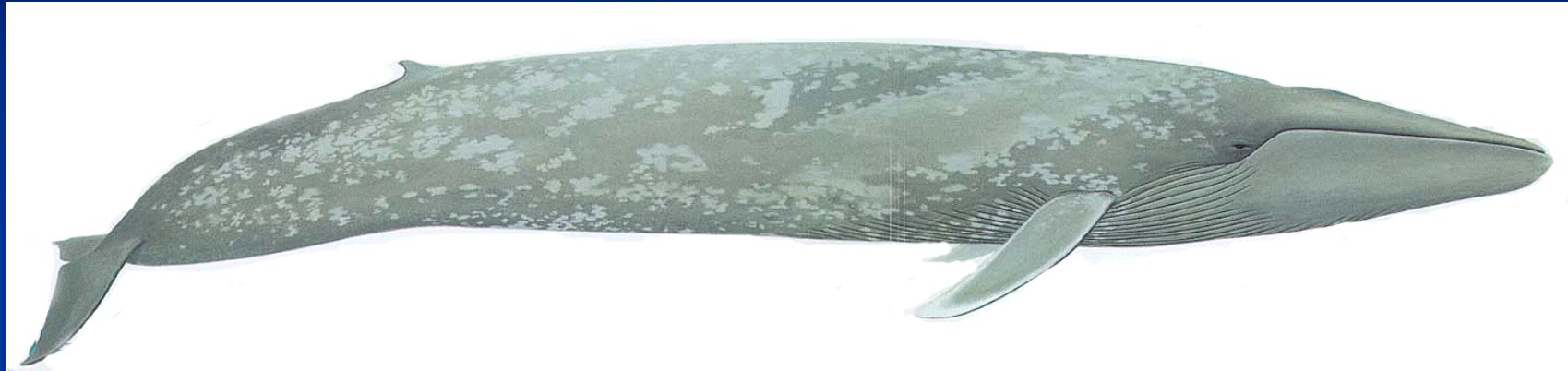
15

Ambient Noise - Rainfall

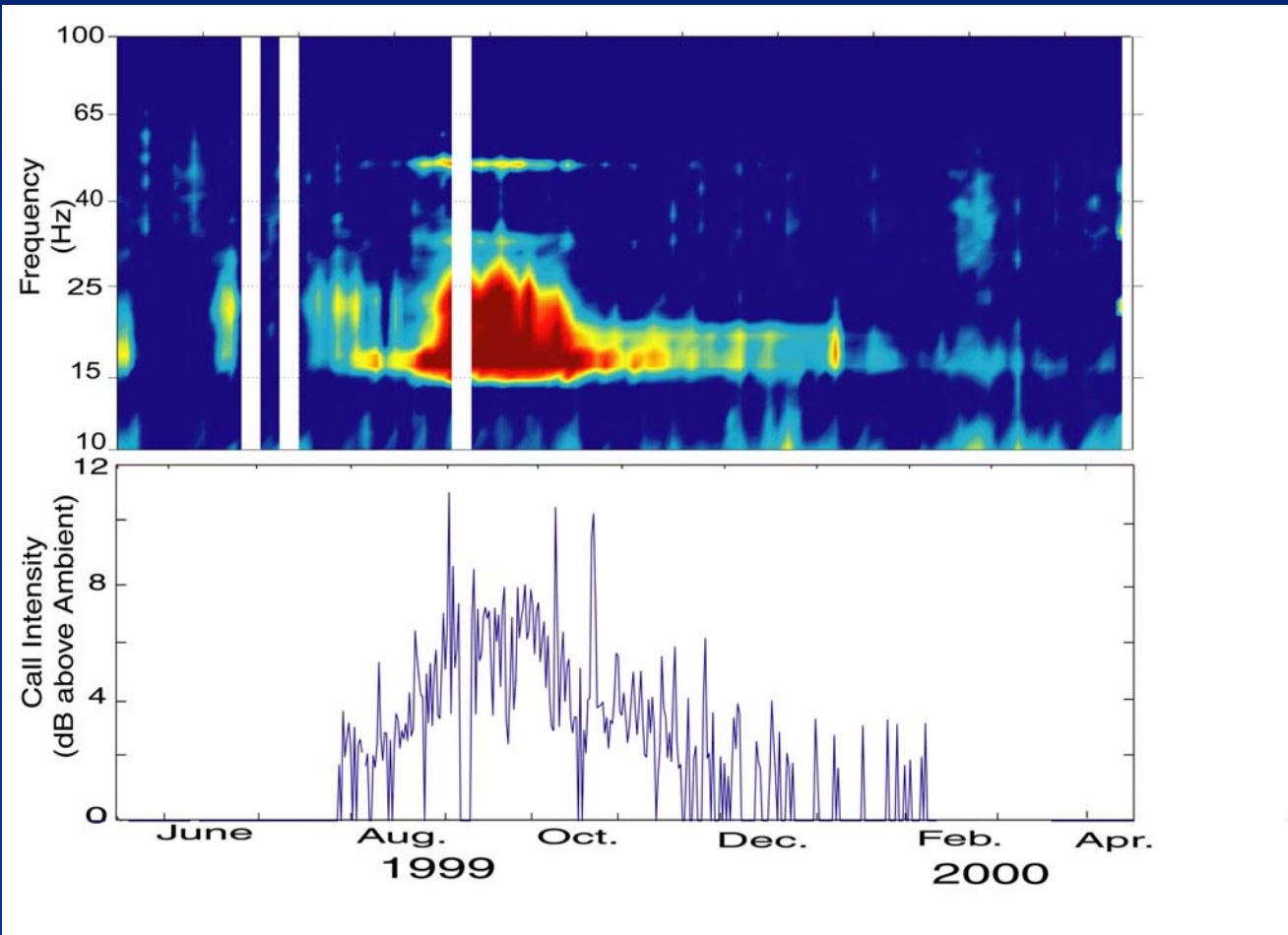


Ambient Noise - Blue Whale

→1m←



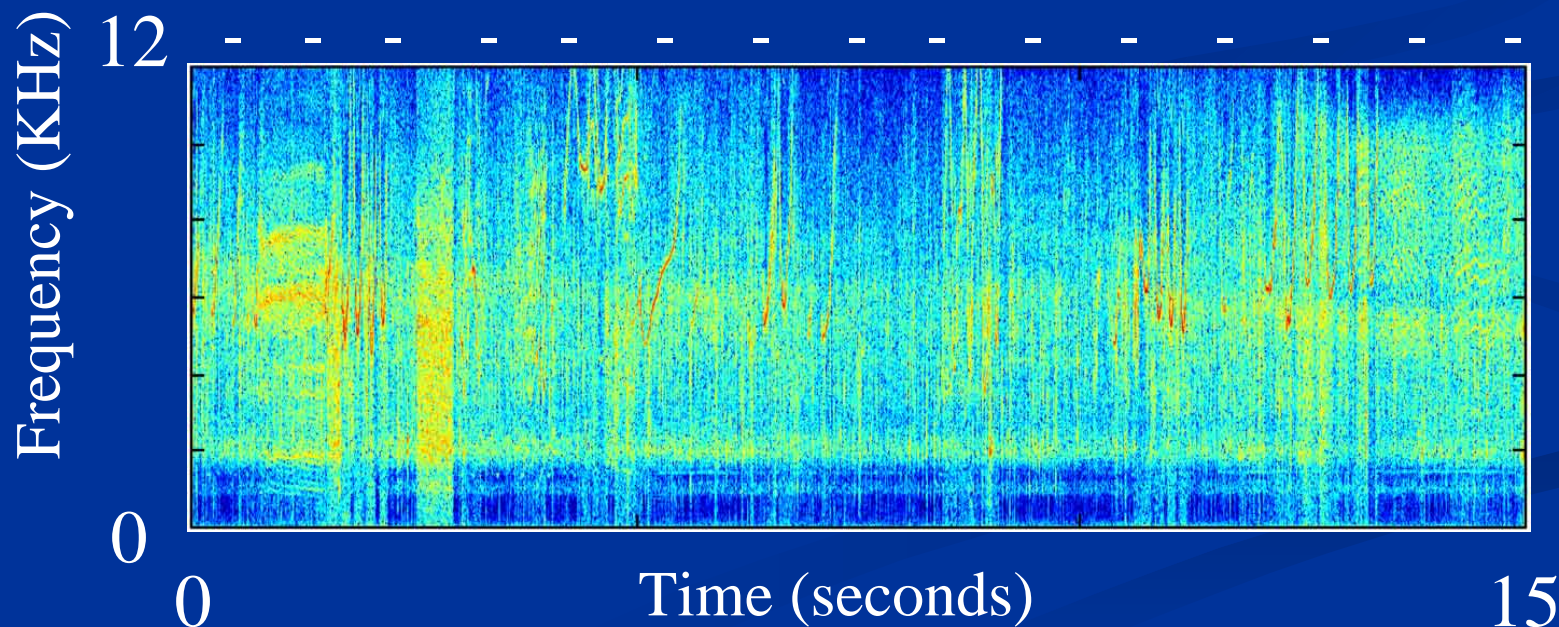
AMBIENT NOISE due to Blue and Fin Whales



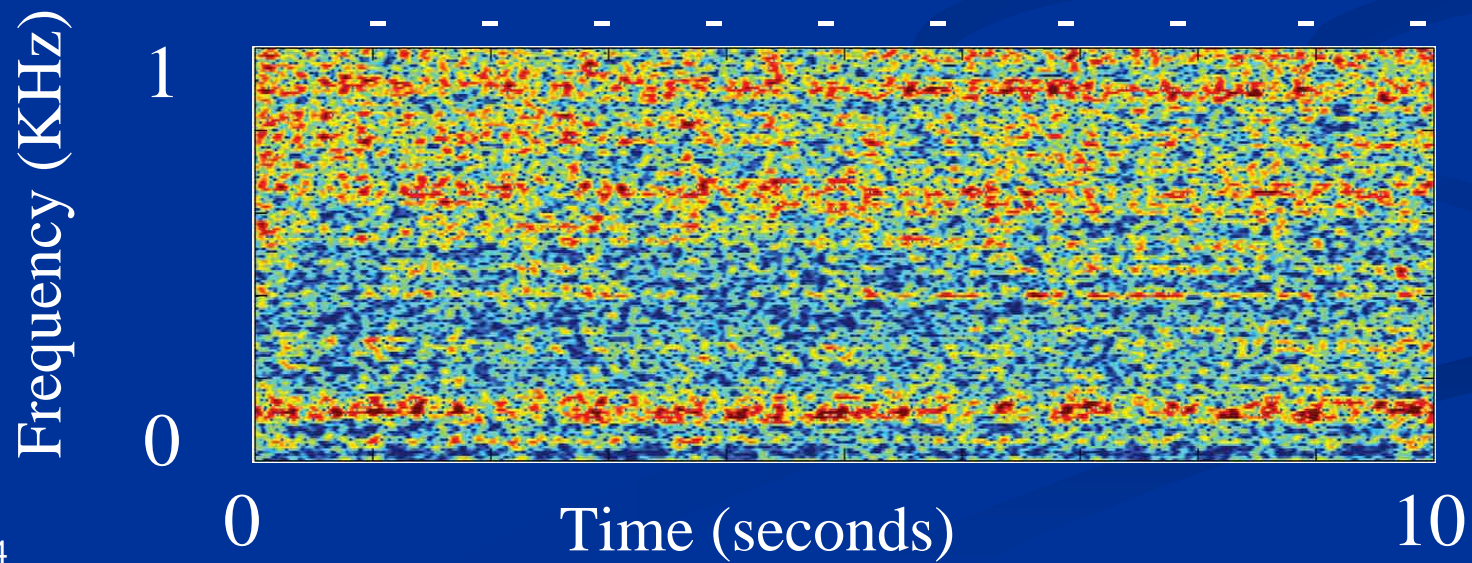
Ambient Noise - Bottlenose Dolphin



1m



Ambient Noise - Ship

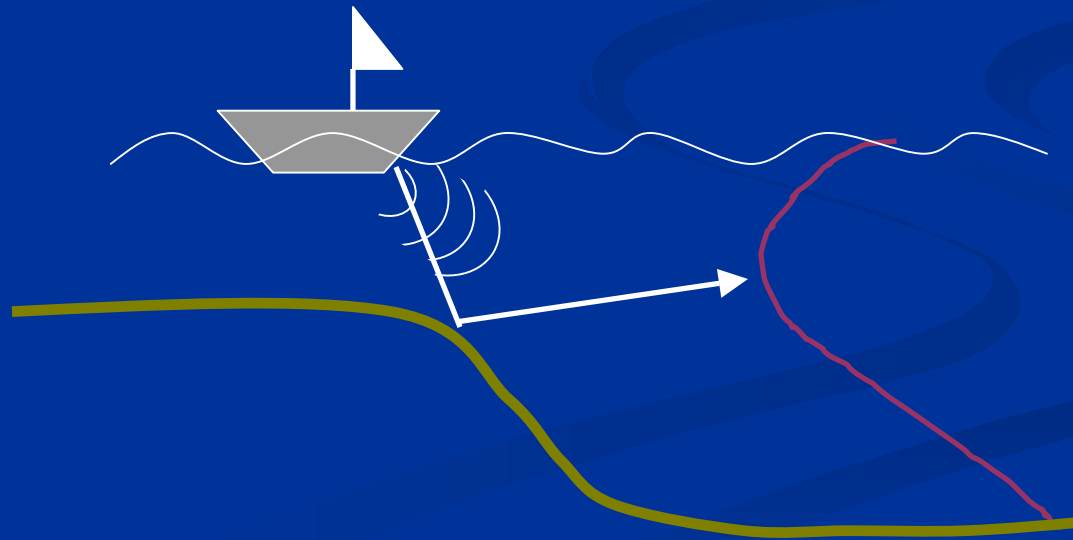


Propagation of Shipping Noise

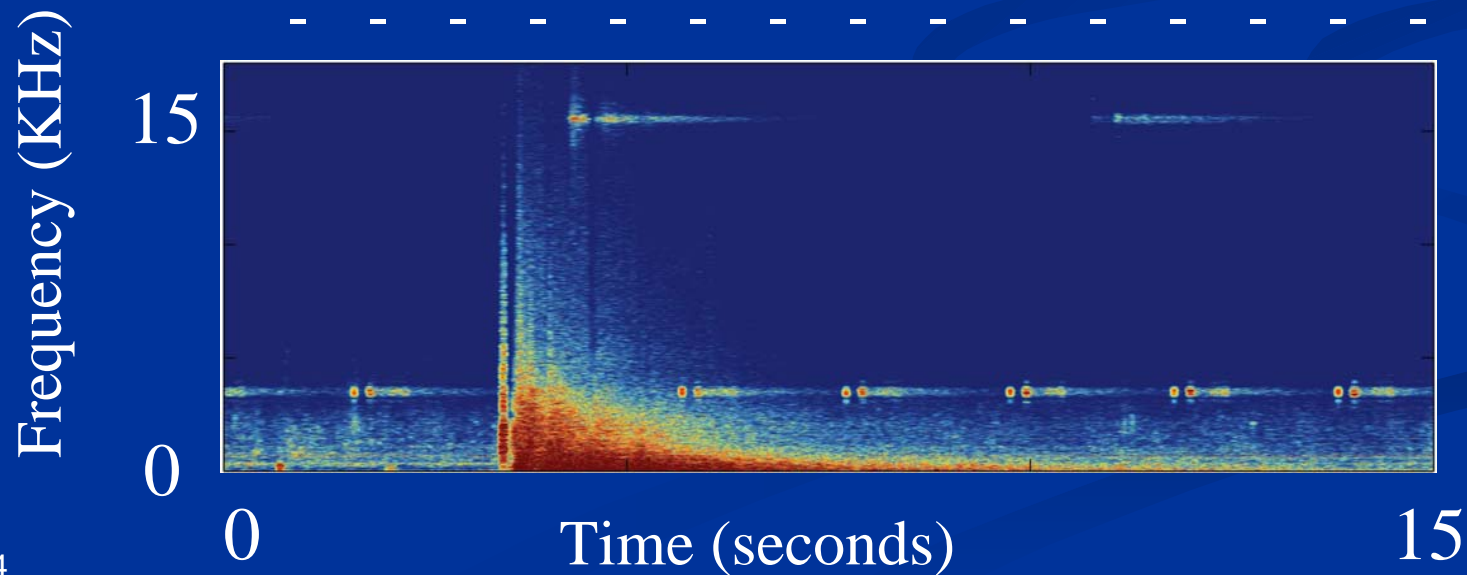
Shallow Water Continental Shelf



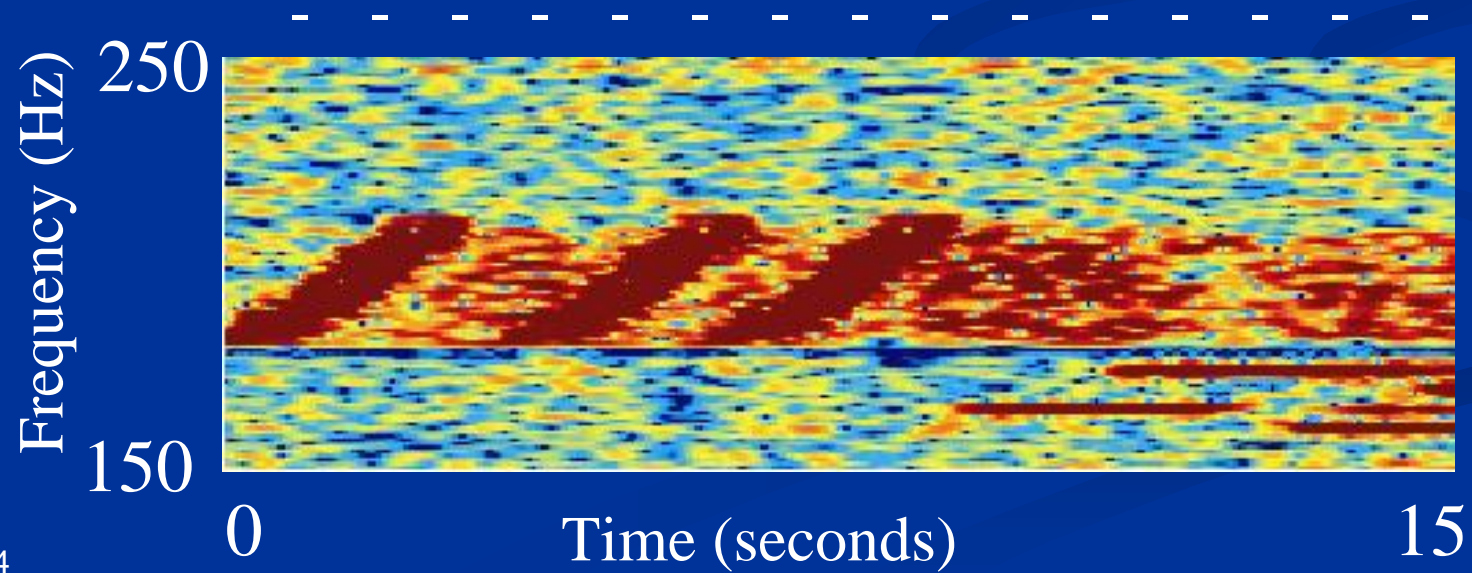
Down-slope Conversion of Sound to Deep Water



Ambient Noise – Airguns and Echosounders



Ambient Noise – Sonar



Anthropogenic Sound Source Levels

FREQUENCY

10-100Hz	100-1000Hz	1-25kHz	25-150kHz	
Underwater Nuclear Explosion				300+ dB
Navy Ship Shock Trial				250-300 dB
Navy LFA	Navy ASW Sonar			200-250 dB
Airgun Arrays				
Research Sonar Experiments	Acoustic Harass Device			180-200 dB
Shipping - Supertanker	Navigation Sonar			
Fishing and Other Vessels				160-180 dB
			140-160 dB	
		Acoustic Deterrent Device	120-140 dB	

SOURCE LEVEL re:uPa@1m

Anthropogenic Sound Energy per Year

FREQUENCY

10-100Hz	100-1000Hz	1-25kHz	25-150kHz	
Underwater Nuclear Explosion				>10e15
Airgun Arrays				>10e14
Navy Ship Shock Trial		Navy ASW Sonar		>10e13
Shipping - Supertanker				>10e12
Navy LFA				
Shipping - Merchant				>10e11
		Navigation Sonar		>10e10
Research Sonar Experiments				>10e9
	Fishing and Other Vessels			>10e8

TOTAL ENERGY (Joules)